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ABSTRACT

A discussion is presented on the development and implementation of two inservice training programs for science teachers which were based on a "constructivist perspective" which is based on the belief that knowledge (in an individual) is always a personal construction. Within this framework, the programs involved the development of both teaching strategies aimed at fostering in the pupils the construction of new knowledge in science, and of training activities aimed at fostering in the teachers the construction of a new teaching style. A description is given of the details of the two inservice training programs, the first of which lasted for 5 years and was devoted to inservice science teachers in the middle school level. All were graduated in mathematics or physics, chemistry, biology, or natural sciences. The second, most recent program, was devoted to elementary school teachers who had received very little training in science at the preservice level. (JD)

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CONCEPTUAL CHANGE AND SCIENCE TEACHER TRAINING: A CONSTRUCTIVIST PERSPECTIVE

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A CONSTRUCTIVIST PERSPECTIVE

"To learn to discover is something but to teach how to discover is something else. I´ve only just started and I´m enjoing it"

(from the report of a Teacher after the training program, 1988)

Introduction

Our contribution is based on the experience of many different training teacher activities carried out by the research group in the last two decades. Among them we have chosen to refer to two in particular in order to make our remarks more concrete.

The first training program lasted five years (1977-1982), with regular weekly meetings along the whole school year (from September to June) and was devoted to inservice science teachers in the Middle School (11-14 year old pupils). The teachers who attended the course, according to the Italian legislation, were graduated in Mathematics or Physics or Chemistry or Biology or Natural Sciences (Grimellini Tomasini, 1981).

Our plan included four modes of action:

- Individual training of teachers both at professional and cultural level;
- Planning of class work, according to the needs of each individual class of students;
- Evaluation of the class work and children´s achievements;
- Coordination of different activities within an unique methodological frame of reference.

The last three modes of action were carried out in real time and provided real time feed-back.

The number of participants was about fifty per year. They were supposed to be different teachers each year but in fact many of the teachers who participated for one year asked to partecipate also in the following. The number of classes involved was more than one hundred per year and the pupils about 2500.

The activities of the program were divided into:

* working group activities

* inter-group meetings and plenary sessions

The working group were six. Each group was coordinated by a member of the research team.

The second program, which has been tried out very recently (1987-1988), was devoted to elementary school teachers who had received very little training in science at preservice level. The program was part of an official plan for training elementary school teachers, put forward by the Ministry of Education. This program has been carried out twice and was attended each time by about fifty different teachers, but some of the teachers who had participated in the first were invited to contribute to the second with the teaching experience developed in their classes after the training activities.

The course consisted of 40 hours of work distributed over a short period of time (1 week - 1 month) and equally divided into plenary sessions or lectures and working group activities.

It may be interesting to note that both programs were born in periods immediately preceeding the advent of a reform of the national curricula (which in Italy are fixed by the Ministry of Education): the new curriculum for the Middle School was in fact enacted in 1979, whereas that for Elementary School will be enacted in 1988/89.

We shall give other details of the two programs in the following sections of this contribution.

What does it mean to be "constructivist"?

There are perhaps different answers to the question. It could also be that, according to theory itself, each of us must construct his/her own idea of constructivism. As a research group we have assumed a very broad definition: "to accept a constructivist perspective means to believe that knowledge (in the individual) is always a personal construction".

Within this framework our research group is involved in the development both of teaching strategies aimed at fostering in the pupils the construction of new knowledge in science and of training activities aimed at fostering in the teachers the construction of a new teaching style. The two kinds of research are strictly interwoven and we think that they have to be so.

In both cases we think it useful to analyse the process involved in terms of conceptual change, because both pupils and teachers have previous ideas (based on some form of common sense knowledge) and both scientific education and teacher training aim at fostering the change of these ideas into more general and fruitful ones.

In the case of the teacher, we think that the construction of a new teaching style involves acquaintance with the constructivist approach itself, linked to the development of a research-oriented attitude to teaching, which, in practice, makes him/her able to understand his/her students and their ideas, to interpret and make use of the hints and suggestions that arise from classroom work, to plan teaching strategies which can play the role of interfacing students ideas and accepted theories.

Three phases in teacher training

When we think about planning a teacher training activity, we think in terms of three phases strictly interwoven. The phases are sequential in that the completion of phase c) requires the completion of phases a) and b), but many cycles between the three phases are possible before completing the process. The phases are:

a) discussion about individual ideas and experiences, triggered by a problem or by a task to perform which aims at creating a situation where the teacher feels the need to make explicit his/her assumptions about teaching and about the discipline to be taught. In other words, making the best of the implicit potential of the teachers and starting to point out possible limits of their ideas.

b) introduction of new ideas concerning science teaching carried out by different means, for example: lectures, experimental activities, analysis of evidences and problems. The challenge of previous conceptions is here more direct and the reaction expected from the teacher is that of trying to fit the new ideas into the old ones, that is to solve conflicts resisting major changes.

c) rethinking about the results of phases a) and b) in a more general framework which should result in the appreciation of the potential of the new ideas and eventually in a conceptual change which have consequences both in the theoretical and the practical approach to teaching.

The idea of three phases is very similar to that put forward by David Hawkins about elementary science education (Hawkins, 1974). We also agree with his ideas of how intellectual habits may develop into "critical barrier" and of the importance to recognise the nature of intellectual habits in order to understand their potential and limits (Hawkins, 1983). We think that they are very useful also when applied to the development of a new teaching style.

In practice, very often, teacher training activities focus on phase b), neglecting phase a) and reaching only very rarely phase c). Phase b) is obviously very important because it is when old ideas are confronted with new ones and it is therefore also the more delicate. What we emphasize is that activities of phase a) are necessary to the success of the rest of the process and that phase c) is sometime considered a "natural" consequence of phase b) rather than a further crucial step.

We had an experience of giving space to phase a) when we carried out the first training program that we mentioned in the introduction. When the program started in 1977 the research works on children´s science had only just started and very little if anything had been published on applying constructivism to science education, nevertheless elements of our future approach to science teaching were implicit in our assumptions. The essence of our assumptions was that a training program, in order to match the needs of the science teachers and pupils at middle school level, should address both professional and cultural aspects and that this could be obtained by inviting the teachers to prepare, discuss

and experiment their own plans of activities to be carried out in the classroom with their students, whose results had to be evaluated within the training activities.

The teachers worked in small groups and were not pressed from the outside: they had time to mess about with their ideas about teaching while they discussed how class work could be planned and carried out.

The ideas put forward by the research team, and which at that time were in fact new for most of the teacher, concerned the active role of the pupils in the learning activities and the importance of experimental work in science teaching.

The external input of phase b) consisted in the new national curricula which they were asked to adopt, in teaching materials to be critically analysed, reviewed and adapted, previous experiences of research in science teaching of those experienced teacher and researchers who acted as group coordinators and only in few occasions lectures on specific topics.

Phase a) and phase b) were in a way interwoven and in our opinion we succeded in helping the teachers to make their "philosophy" of teaching explicit and to develop the potential of their ideas. We also prepared the way for future development but most of the teachers did not reach phase c): the process they underwent was more of assimilation of new ideas then of accomodation, they improved their teaching style but did not really change the assumptions on which it was based.

Looking back to that training program we have lately pointed out something which was missing and could be crucial for attaining phase c). We think we did not care enough about disciplinary knowledge. Reacting to the old fashion view of teaching "he who knows something also knows how to teach it" we fell into the trap of putting more emphasis on pedagogical issues thinking that the disciplinary knowledge necessary for planning and carrying out classroom activities could be simply extracted from textbooks when needed. We have deeply modified our position about this issue: we tend to say now that disciplinary knowledge must be not only cultivated with great care but also reviewed and reconstructed on a personal basis, the ability to master it being the key to understanding the ideas of the pupils, to recognizing that they are not simply mistakes but the evidence of something deep which has to do with the individual cognitive structures and the structure of disciplinary knowledge.

The results of an experiment on teacher training described in a recent paper by Hewson and Hewson (1987) seem to reinforce our arguments. In the discussion the authors point out that some of the teacher failed to identify "...any instructional problem resulting from students' conceptions they had elicited in the interviews. In other words, for them, if the problem does not exist, there is no need to use problem solving measures." We have recognized this attitude also in some of the middle school teachers during the training activities (Grimellini Tomasini et al., 1983). Our opinion is that very sound disciplinary bases are also required in order to recognise that there is a problem.

They allow the teacher to identify the implications of pupils' conceptions and to develop conceptual change strategies apt at addressing the existing problem.

In our opinion the process of conceptual change in the teachers can only be successful if it concerns both their teaching style and their knowledge of the discipline. The process has also to be made explicit in order to play the role of an example of conceptual change for the teacher to be used to understand the process of conceptual change in the students.

The role of disciplinary knowledge was emphasized in the second training program that we mentioned in the introduction. The lack of knowlege in science and particularly in Physics in Italian elementary school teachers is so well known and taken for granted that it came very natural to start with the study of a phenomenon from the point of view of the Physics involved. It also came very natural to start with some messing activity about the phenomenon to be studied.

The elementary scool teachers appear to recognize the analogies between their messing about and that of their pupils more easily than their secondary school collegues. As a result of their previous experience, they seem to have established a relationship with their pupils which better fits in with a constructivist approach. They are curious about children's ideas and accustomed to respecting their opinions. One reason may be that, lacking a formal disciplinary reference, they are less concerned with conveying disciplinary knowledge as such, but rather with helping the children to develop their own abilities.

Trying to apply the C.C.M.

How does the conceptual change model by Posner at al.(1982) fit in with the above remarks about teacher training? We think of this model as a good instrument to obtain a global view of the C.C. process, pointing out necessary conditions for the process to occur.

The model seems to work very well a posteriori in that it suggests **why** the change occurred (or did not occur). Its application to teachers has been discussed elsewhere (Posner, 1983; Grimellini Tomasini et al., 1984; Hewson and Hewson, 1987), we wish to emphasize that it is compatible with the description of the process discussed above. In our opinion, the three phase description is in a way complementary, giving a picture of **how** the process can occur, by making explicit three different phases of the process. This idea can be exemplified as follows:

- phase a) may induce **dissatisfaction**, which can arise from not being able to solve a problem, whatever it may be, and implies the need of thinking about the possessed knowledge in order to identify its potential and limits.

- phase b) requires an external input which can be new ideas, new hints for looking from different perspectives, new experimental data. This

phase will develop if the input is **intellegible** and **plausible**, otherwise the development is very unlikely to be triggered.

- phase c) eventually is the final point of a satisfactory process of conceptual change if its outcome is to be able to design teaching plans which are considered **fruitful** in the classroom practice, aimed at inducing a conceptual change in the pupils. The irreversibility of the process could be used to evaluate that the process really occurred; if the final state corresponds to a state of equilibrium where old ideas and schemes have been reconstructed in the light of the new ones, the system (the style of thinking) is very unlikely to go back to situations (states) that should now appear less plausible and fruitful, although intellegible. But the fundamental result of phase c) should be the ability to produce teaching strategies and materials according to the new perspective.

The analogy between C.C. in the pupils (from intuitive common sense knowledge to accepted scientific knowledge) and C.C. in the teachers (from common sense teaching style to research oriented teaching style) is very strong but this does not mean that the path followed should be the same: the role of the different phases and even more important the times required for the change to occur may be very different.

Researchers and conceptual change

Can we also speak of conceptual change in the researchers involved in teacher training? Speaking for us, yes.

When we think about our first experiences of pre-service and in-service teacher training (which for some of us date back to more than twenty years ago!), we must admit that the C.C. occurred is remarkable and that further changes are likely in the future.

It would be interesting to extend the comparison of the different conceptions of teacher training to all those involved in teacher training. We shall probably find how difficult it is to argue about the ideas on which the designs of the programs are based. Teacher training programs based on the idea that knowledge results from an accumulation process, in which academical lectures on formal subject matter play a major role and the discussion of the bases of the discipline is neglected so as the active role played by the teacher in mediating knowledge, is still very common in Italy. This is also what experts asked to do by the institution. In fact in teacher training activities organized by the Italian Ministry of Education lectures are payed 2.5 times more than the job of coordinating small group work, the time spent being equal and the expert being the same.

Working shoulder to shoulder with the teachers and having direct experience of implementing teaching strategies in the classroom are the main elements that contributed to our change of approach towards teaching and teacher training (Grimellini Tomasini et al., 1984, 1987). Only when a strong link between research in science teaching and teacher training is established does it become possible (and plausible,

intellegible, fruitful...) to interpret the results obtained from different perspectives. In other words also a constructivist picture of teaching and learning may be the result of the phase c) of a process of C.C. in the researchers which started with a deep feeling of dissatisfaction based on the consciousness of the fundamental role played by the teacher in the classroom.

What teaching materials do we need

We believe that the issue of materials for teacher training should be treated wih particular care. We think that it is not enough to work with the teachers both on disciplinary aspects and problems in designing teaching strategies pupils´conceptual change-oriented, but it is also necessary to provide them with materials to be analysed individually in order to trigger a reconstruction also at individual level, that corresponds to real understanding of the material itself.

A risk that must not be underestimated is that of "producing" teachers...researcher-dependent instead of teachers research-oriented!

It may not be easy to prepare something suitable for this purpose. In our opinion materials consistent with a constructivist perspective of teaching and teacher training should:

* be designed in small working groups in which both researchers and teachers are present;

* refer to the reality of the teaching practice;

* contain evidences of real classroom activities, documents of children´s science, successes and unsuccesses, changes of direction and the reasons for, solved and unsolved problems, etc.;

* contain reflections, at the adult personal level, about the structure of the discipline related to the topic under study;

* suggest a wide range of alternative solutions;

* be flexible in its application to classroom practice.

We wish to make our doubts explicit about the so called teaching units. This kind of teaching materials have come into fashion in Italy in the last decade and for many educators they are not yet out of date; productivity of research groups is often measured by the number of teaching units produced! We think that this material is a double-edged weapon. The risk that they become a cooking book to solve every problem instead of being the useful reference to match the teacher´s real needs is very high.

At present new materials are being published in Italy, within a project supported by the Italian Research Council. Research groups in Physics education from six universities (Bologna, Milano, Pavia, Pisa, Napoli, Roma) collaborate in the project. The materials are thought to be

"instruments to develop scientific culture at the compulsory school level" and are written for the teachers from kindergarden to middle school. The project will produce twelve booklets (P.Guidoni is the series editor) concerning different topics and addressing different levels in compulsory school. At present seven booklets have been published. Our contribution in the series concerns an experiment on teaching and training teachers to teach about "floating and sinking". It contains our experience on this topic developed during the teacher training program with middle school teachers mentioned above, reviewed in the light of our C.C. about how to work with pupils and teachers.

Some final remarks about directedness

It does not seem to us that strictly directed programs can be compatible with a constructivist perspective of teacher training and Science teaching. In this sense our view of constructivism is rather strong. This does not mean however that there should not be elements of directedness in designing a teacher training program.

There are elements of directedness that are unavoidable: the researchers who run the program must take decisions which have a great influence on the development of the activities. This does not contrast with our general view provided that we are ready to modify our decisions in the light of the teachers' contributions.

It seems that the same program can be at times more directed and at times less directed. This may depend upon boundary conditions such as preservice training or previous experience of the teachers involved.

The construction of materials fitted to the teacher's own teaching is a final unavoidable step in our constructivist perspective but interpretation and adaptation of materials may be necessary at some stage. Conceptual change oriented curriculum materials are therefore important but should be seen as something to be revised and in a way overcome.

The input of new ideas will certainly contain explicit information about the nature and function of students' alternative frameworks and the model of conceptual change but the impact of such ideas is unlikely to be decisive unless teachers have been encouraged in developing and discussing their own conceptions of teching and learning.

Information about the results of the research works on pupils' alternative frameworks and teaching strategies should be made available to the teachers, but children's ideas will not be seen as a problem unless he/she has developed ways of focussing on students' perspectives. In order to do that sound disciplinary bases which enable the teacher to "read between the lines" of pupils'talks are fundamental.

Finally the number of teachers involved in a program may determine the minimum level of directedness which can be accepted. If the number of teachers involved must for some reason be very large, for example when new curricula are implemented on a national basis, we believe that a

real conceptual change in the majority of the teachers is very unlikely to occur in a short while.

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